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POTATO WART

By R. E. Hartman and W. A. McCubbin
Bureau of Plant Industry

Various Degrees of Wart Development on Potato Tubers

F. P. Willits, Secretary of Agriculture.

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PENNSYLVANIA DEPARTMENT OF AGRICULTURE.

Organization and Services.

FRANK P. WILLITS, *Secretary* JOHN M. McKEE, *Deputy Secretary*

This Department is essentially a service agency created by legislative enactment to deal with administrative, regulatory, investigational, and educational problems which can best be solved through public rather than individual action. The organization provides for coordination and cooperation with the Pennsylvania State College and the U. S. Department of Agriculture. The Department operates through the following bureaus:

ANIMAL INDUSTRY: T. E. MUNCE, *Director and State Veterinarian.*

Prevents and eradicates transmissible diseases of animals and poultry, including tuberculosis of animals in cooperation with Federal Government.

Demonstrates to veterinarians control methods for transmissible animal diseases;

Supervises vaccination for and the prevention of hog cholera, anthrax, black leg and hemorrhagic septicemia;

Protects public from unwholesome meats through ante and post mortem examinations of animals at slaughtering establishments;

Inspects, licenses and furnishes information as to breeding, soundness and conformation of stallions and jacks standing for public service;

Enforces law requiring licensing of dogs and providing for protection of livestock and people from attacks of uncontrolled dogs;

Maintains laboratory for diagnostic research and experimental projects.

PLANT INDUSTRY: C. H. HADLEY, *Director.*

Tests agricultural seeds for purity and germination, and enforces State Seed Law;

Inspects orchards, parks, farms, and plant imports for injurious insects and plant diseases;

Inspects and licenses Pennsylvania nurseries, and licenses all dealers in nursery stock;

Enforces laws governing apricultural practices, disease control and housing;

Places and enforces quarantines and carries on eradication campaigns against insect pests and plant diseases;

Inspects and certifies potatoes for seed purposes;

Makes investigations for the control of injurious insects and plant diseases including field tests of insecticides, fungicides and weed killers;

Maintains collections of insects, plant diseases, plants, and seeds, and identifies specimens.

FOODS AND CHEMISTRY: JAMES FOUST, *Director.*

Accomplishes its purpose of protecting Pennsylvania homes against harmful foodstuffs by sampling, analyzing, and bringing prosecution under the laws relating to foods and non-alcoholic drinks, including milk, cream, butter, ice-cream, eggs, sausage, fresh meats, soft drinks, fruit syrups, vinegar and kindred food products;

Regulates and issues licenses for the manufacture and sale of oleomargarine;

Licenses and regulates egg-opening plants and cold storage warehouses, maintaining regular inspection and enforcing twelve-month storage limit;

Inspects milk plants and creameries and regulates weighing, testing, buying and selling of milk and cream on a butterfat basis;

Protects honest manufacturers, importers, selling agents and ultimate users of feeding stuffs, fertilizers, lime products, linseed oil, paint, putty, turpentine, insecticides and fungicides, by means of annual registrations followed by inspections, analyses, prosecutions and the publication of the analyses of these products;

Analyses special samples for residents of the State at the rate of $1.00 a sample for feeding stuffs, lime products and linseed oils.

MARKETS: P. R. TAYLOR, *Director.*

Investigates and assists in the marketing of farm products; at present chiefly grain and hay, fruits and vegetables, poultry and eggs, and tobacco;

Compiles and distributes daily market information as to supplies, shipments and prices;

Advises growers on transportation of agricultural products;

Assists cooperative associations and public markets;

Establishes standard grades of farm products and maintains inspection;

STATISTICS: L. H. WIBLE, *Director.*

Assembles and disseminates essential statistics and facts pertaining to the agriculture of the State, from monthly reports rendered by hundreds of volunteer crop correspondents, information which assists the producer in his sales and interests all industries which deal with agricultural products;

Cooperates with U. S. Bureau of Agricultural Economics in joint crop and livestock reporting and publishes annual and monthly summaries of the data;

Compiles dates of county and local fairs and assembles data pertaining to their success and results during each year.

SUMMARY

Potato Wart was probably introduced into America about 1912 in table potatoes brought in to relieve a crop shortage.

It occurs in three states, Pennsylvania, Maryland and West Virginia. In the last two states the infected areas are very small.

In Pennsylvania, Wart has been found in 11 counties in the anthracite and bituminous coal regions; in these counties 813 gardens in 58 towns and villages are known to have Wart. The total area of the infected gardens is about 100 acres.

The disease appears only on the underground parts on which it occurs as irregular outgrowths of warty tissue of varying size, suggesting a cauliflower in appearance. The plants are not killed and the tops are normal, but the tubers are partially or completely replaced by the warty outgrowths. Warted potatoes rot readily.

Potato varieties differ in susceptibility to Wart, some being very readily attacked and others completely immune.

The Rural types widely grown in Pennsylvania are all very susceptible.

The organism produces immense numbers of spores in the warty tissues which are mixed with the soil, where they may remain alive for many years.

Wart is spread by diseased tubers or by contaminated soil or by any means which will carry infected tubers or soil. Potatoes, root crops, garden refuse, manure and any plants with earth about the roots may spread Wart.

Control of Wart is obtained by a quarantine which prevents the movement of potatoes or other dangerous materials, and by the use of immune varieties.

Breeding research gives promise of the ultimate production of an immune variety which can satisfactorily replace the popular Rural.

Eradication of Wart while theoretically possible has such practical difficulties that success would be doubtful.

The quarantine system offers the most feasible method of dealing with our Wart problem at the present time.

POTATO WART

By R. E. Hartman and W. A. McCubbin.

INTRODUCTION

The history of the Potato Wart disease in America is typical of what happens when a foreign parasite is introduced into our country and establishes itself at the expense of our agricultural industry. The introduction of Wart does not stand alone in this class of undesirable immigrants; it is but a recent arrival in a long and imposing series of introduced foreign insects and diseases that have been allowed to enter and then have spread in our crops, to become an additional burden on our farming industry. The aggregate damage by foreign pests now widely established in this country mounts into many millions of dollars annually, and the cost of quarantine, control measures and spray materials which we are compelled to use against them is an appalling load on our already sorely burdened agriculture.

The Federal foreign plant quarantine act of 1912 was intended to provide a barrier against the invasions of foreign diseases and insects. It is well known that there are thousands of these pests in all parts of the world which may be comparatively harmless in their own lands, but which, if introduced into America, are capable of running riot and repeating the accomplishments of Citrus Canker, Boll Weevil, Gipsy Moth, White Pine Blister Rust, Chestnut Blight, Japanese Beetle and Potato Wart. If the foreign plant quarantine can prevent future introductions of these destructive enemies, it will confer an inestimable benefit on American agriculture by permitting it to develop in peace and security, free from constant menace and not subject to frequent drastic changes or to the expenses, handicaps and irritations that unavoidably accompany every struggle against a new pest.

HOW POTATO WART WAS INTRODUCED

The Potato Wart disease was introduced into the United State by means of potatoes imported from the British Isles or Europe. During the years of 1911 and 1912, a serious shortage in the potato crop of the United States, led to the importation of several shiploads of potatoes which were distributed in carload lots to the mining and industrial centres of Pennsylvania and other nearby states. It is doubtful if many of these potatoes were planted, but the potato refuse and wash water of those consumed undoubtedly found their way into the gardens of these districts and infection followed. In this way the Wart became established, but owing to the fact that most of the inhabitants in these mining towns were foreign born, and out of touch with our agricultural agencies, the disease remained undiscovered until the fall of 1918, when specimens were sent for identification to the Pennsylvania Bureau of Plant Industry, at Harrisburg.

As soon as the presence of Wart was thus made known, both Federal and State authorities jointly carried out a hurried local survey to determine the limits of the infection and the towns and villages found to be infected were placed under quarantine by the Pennsylvania Department of Agriculture. Since that time scouting on a much larger scale has been carried on in Pennsylvania and other eastern states, and as new infections were discovered the quarantine area was increased. At the time of the present writing, the Wart disease has been found in fifty-eight towns and villages in eleven counties of Pennsylvania, in six towns or villages of Maryland, and in two in West Virginia. Without exception, the towns and villages containing Wart infection in the three states mentioned are isolated mining or industrial centres. That more purely agricultural communities have escaped infection can only be attributed to the economic circumstances attending the introduction of Wart; the mining towns involved felt the shortage of potatoes quickly and keenly, and they had in their company store systems the machinery for buying and handling car lot shipments, and so these foreign potatoes came naturally to them.

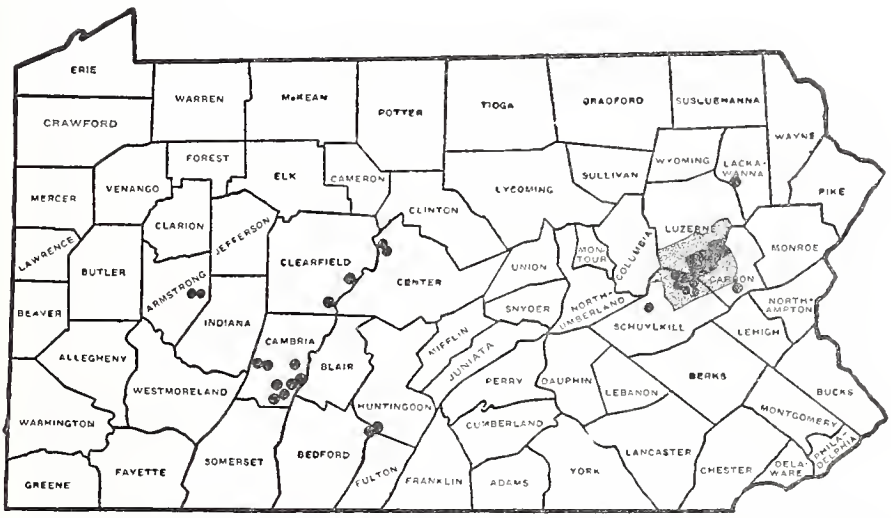

Fig. 1. Map of Pennsylvania showing location of all Wart infections (black), and the safety zone (dotted). The towns shown by the black dots and the area shown in solid black are under strict quarantine.

DESCRIPTION OF THE DISEASE

The Potato Wart disease *(Chrysophlyctis endobiotica* Schilb.) is a fungus soil organism of low type, which attacks the tender underground portions of the potato plant and occasionally the stalk and branches at points where they come in contact with the soil. The fungus in no case kills the potato plant, nor does it stunt the growth of the top or produce any noticeable symptoms on the foliage. A potato plant may be badly attacked by the Wart and yet have a top that is quite vigorous in growth and normal in appearance. It is only on the underground part or parts touching the soil that one can look for the typical outgrowths of irregular tissue which are so characteristic and which have given the disease its name. These

irregular masses of warty tissue are at first almost white in color, and their general appearance at this stage readily suggests a cauliflower; later on they turn dark brown or nearly black, except where they have pushed up out of the soil and become sunburned or greened as any potato will do when exposed to light.

The Potato Wart disease is first observed as warty outgrowths on the tender underground roots and stolons, the infection appearing in a normal season about the middle of July. If the variety grown is susceptible, the fungus attacks the tubers as soon as they are formed and irregular growths appear about the eyes and lenticels; even before the formation of tubers, the stolons may be attacked and cases have been observed in which stolon infection was so severe that no tubers were formed during the season. The Wart develops rapidly after infection occurs and in a few weeks' time the abnormal tissues may reach considerable size. There is great variation in the size and number of the warts; this is partly a matter of varietal susceptibility, partly a result of the number of infection points, and partly a question of the extent of tuber development at the time of infection. Because of these uncertain factors the warts as seen in the field may show a wide range of characters. In some tubers or stolons there may be very small outgrowths readily overlooked, while in other cases the whole tuber may be transformed into an irregular warty mass. Between these two extremes all stages are to be seen.

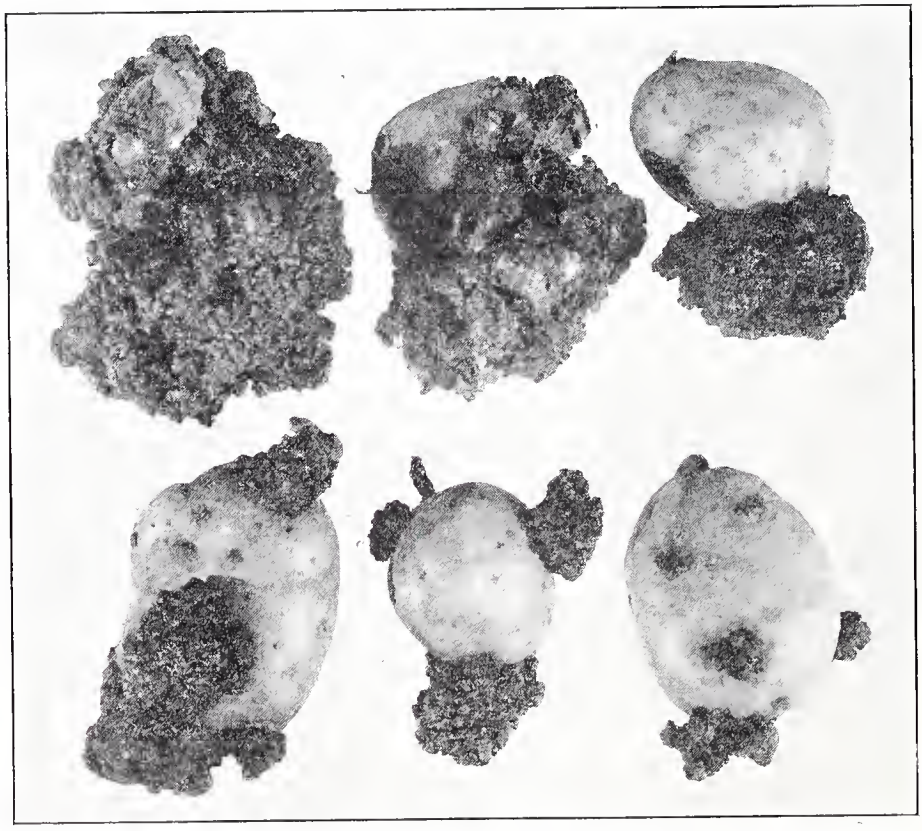

Fig. 2. Wart on the tubers varies from small outgrowths at the eyes to a complete replacement of the tuber by warty tissue.

Under very favorable conditions these warty tissues grow to such size that they may push out of the soil and appear above ground. However, such excessive development occurs rarely and the presence of the disease is usually detected only when the earth has been removed from about the roots and tubers at the base of the stalk.

The fungus is propagated by means of minute bodies called sporangia, too small to be seen by the naked eye. They are formed in immense numbers in the outer layers of the warted tissue and are of two kinds, (a) summer sporangia and (b) resting sporangia. The summer sporangia, if conditions are favorable, soon open to set free a large number of motile spores, which are capable of infecting other parts of the plant thus producing new Warts within a short time. These motile spores however are capable of moving only a very short distance in the soil, so that the spread of the disease to new plants or over a large area by spore movement is not rapid. The thick walled resting sporangia lie dormant for long periods and though a great number germinate each year, it is apparent that some of them lie dormant for five, or possibly ten years. This persistency of the resting sporangia in the soil makes crop rotation of little value in the control of Wart for it is useless to omit planting potatoes for a few years in the hope that the disease will die out.

The tough impenetrable skin, which protects the ordinary potato from the attacks of organisms which cause decay, is poorly developed over the wart outgrowths; consequently the warty tissue is very susceptible to rot and the wart masses formed early in the season soon decompose and decay, thus liberating their myriads of spores into the surrounuding soil. The wart masses formed toward the close of the season may still be quite fresh at digging time. But tubers which bear such warts cannot stand storage, since the soft, unprotected tissue of the warted portion rots within two or three weeks in storage, and with it the whole potato.

The extent of the infection under conditions favorable to the fungus is determined by the susceptibility of the variety grown. In general, the common American potato varieties can be classified as immune, resistant or susceptible. Varieties which can be classified as immune are absolutely free from the disease; they can be grown in the worst infected soil and yet show no trace of Wart. Resistant varieties are attacked in varying degrees; in some varieties only minute growths occur on the tubers, and the roots and stolons are likewise only slightly attacked; in certain other resistant varieties the tubers may be resistant whereas their roots and stolons are severely attacked; while in still others these conditions are reversed, the roots escaping and the tubers developing Wart in a pronounced manner. Susceptible varieties when grown in infected soil are severely and generally attacked and when Wart has been present in the soil for a few years such varieties rarely produce more than fifty per cent of a normal crop.

Fig. 3. Susceptible potato varieties in badly infested soil not only may have enormous Wart outgrowths on stems and roots but may have every tuber replaced by a mass of Wart, as shown in these two plants.

HOW THE DISEASE SPREADS

It is apparent from the above outline of the disease that the spread of the organism can be most easily brought about through any agency by which live spores can be transferred from one place to another, such as seed potatoes, table potatoes, manure, vegetables or root crops, tools, machinery, etc.

Of all these possible means of spread the most dangerous is that of potatoes grown in infected soil. Seed potatoes from such soil are capable of spreading the disease even though apparently free from disease, due to the presence of spores* on their surface or in adhering soil, and table potatoes though they be consumed are also a dangerous source of infection, since their peelings and wash water are capable of spreading the disease to garden or field. Manure is also a very dangerous material, since it is so likely to contain refuse from gardens, or potato peelings, and may even contain spores derived from raw potatoes fed to animals.

All vegetables and root crops, or any plant such as fruit trees, ornamental shrubs, flowers or young tomato or cabbage plants may be a means of spreading Wart, since spores are readily carried in the adhering soil. The common habit among farmers of exchanging baskets, bags and other containers with people in the Quarantine Area is an exceedingly dangerous practice, since such containers are extremely liable to carry Wart in adherent dirt.

*For popular use it seems more desirable to use this term than the more correct "Sporangia".

The Wart can be spread by earth adhering to implements and the shoes of men and several actual instances of transmission in this way are known. This point is of considerable importance since the farmers in districts surrounding the infested area make a practice of securing their extra labor at potato digging time from the small mining towns of the Quarantine Area. It is altogether possible that the Wart organism could be carried to the farming districts in the soil adhering to the shoes of the pickers, if they had previously worked in their home gardens and the soil in which they worked was infected with Wart.

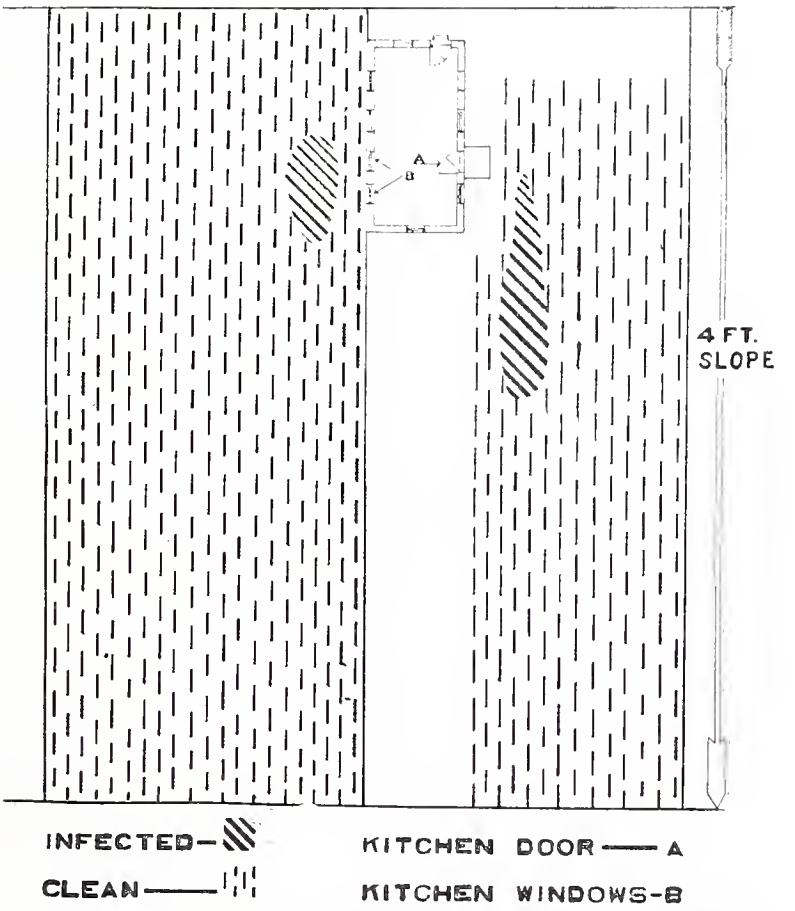

Fig. 4. Diagram of an actual case of Wart in a garden of one of the mining towns in Western Pennsylvania. The slope of the garden and the position of the doors and windows of the house indicate that the disease was introduced into the soil by wash water or peelings of potatoes.

The surface flow of water can easily carry the Wart organism from infected gardens to land below. On the other hand, wind, which plays a large part in spreading many other diseases, is not considered to be a vital factor in spreading Wart, since the organism is so closely bound up with the soil.

The Wart disease has shown a general tendency to spread in many towns of the quarantine area. The first survey in 1918 showed two hundred and fifty-eight (258) infected gardens; this number was increased to six hundred and thirty-five (635) in 1919, to seven hundred and eighty-nine (789) in 1920, to eight hundred and five (805) in

1921, to eight hundred and thirteen (813) in 1922, but no additional infections have been reported in 1923. It is, however, quite certain that a large part of this apparent increase between 1918 and 1921 may be accounted for by the increase in the area under survey as well as by the discovery in later years of infections which were not seen earlier because immune varieties had been used or potatoes had not been planted.

That Potato Wart has apparently not escaped from the mining and industrial districts into which it was first introduced is one of the outstanding and encouraging features of the disease, a feature which is almost unique in our experience. Although there is good evidence that it entered the state about 1912 and had ample opportunity to spread in the six years before it was discovered and a quarantine established, yet the surveys conducted in Pennsylvania and other states in the years 1919-1922 by the Department of Agriculture and the Federal Plant Disease Survey have shown no indication that the disease has spread except in a very local way. This fortunate sluggishness of spread may be attributed largely to the above mentioned fact that Wart is closely tied up with the soil and thus spreads with difficulty except where carried by human agencies. The most favorable factor however in this failure to spread has been the natural geographical and economic isolation of the districts into which it first entered. In practically every case these towns and villages are set in wild uncultivated country with little or no farm land adjacent to them. Since these communities are mining or industrial centers the natural flow of materials likely to carry wart is in all cases inward rather than outward. They consume much more than they produce and send out practically no products that could be dangerous. This happy situation was a clear bit of fortune, for if the disease had ever reached agricultural areas the natural distribution of potatoes and other things would have spread it far and wide.

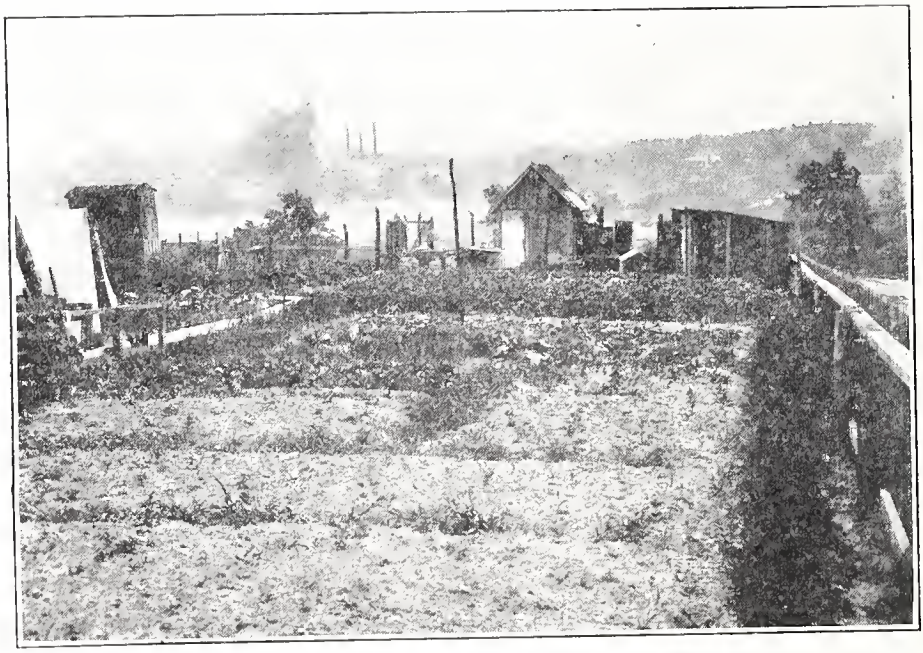

Fig. 5. Garden plot in mining district typical of those in which Potato Wart is found.

The following table gives the number of infected gardens in each of the towns or villages of the Quarantine Area in which Wart has been discovered:

INFECTED GARDENS IN THE QUARANTINE AREA

	No. Gardens in town	Number of Gardens Infected					
		1918	1919	1920	1921	1922	1923
Beaver Meadows,	228	0	1	1	1	1	1
Beaver Brook,	103	2	16	16	16	16	16
Beaverdale & Lloydell,	300	0	0	2	2	2	2
Coxville,	94	6	25	36	36	39	39
Centtown,	21	0	7	12	12	12	12
Coleraine,	59	0	0	1	1	1	1
Drifton No. 1,	128	16	35	43	43	43	43
Drifton No. 2,	135	0	5	6	6	7	7
Dunlo & Llanfair,	390	0	11	13	13	13	13
Ebervale No. 1,	44	2	5	5	5	5	5
Ebervale No. 2,	24	7	11	11	11	11	11
Ebervale No. 3,	68	3	6	6	6	6	6
Eckley,	167	10	69	83	83	83	83
Freeland,	600	6	28	39	39	39	39
Farms, (Michael Becker, Butler Valley),	134	0	1	1	1	1	1
Hazel Brook,	100	1	5	9	9	9	9
Hazleton,	6,000	7	18	28	28	28	28
Highland	104	104	104	104	104	104	104
Highland No. 2	3	0	2	2	2	2	2
Humboldt,	56	1	9	10	10	10	10
Harwood,	142	1	2	2	2	2	2
Honey Brook No. 1,	22	0	3	3	3	3	3
Honey Brook No. 2,	62	0	20	20	20	20	20
Jackson,	105	2	2	2	2	2	2
Jeanesville,	166	7	27	33	33	33	33
Japan,	77	9	1	1	1	1	1
Jeddo,	165	0	0	2	2	2	2
Kelayres,	154	0	11	10	12	12	12
Lattimer No. 1,	155	0	1	1	1	1	1
Lattimer No. 2,	120	0	0	1	1	1	1
Leviston,	16	2	10	20	10	10	10
Lilly,	325	0	1	1	1	1	1
Mauch Chunk,	290	1	1	1	1	1	1
McAdoo,	388	0	15	17	17	17	17
Moosic,	500	0	1	2	2	2	2
New Cranberry	86	3	21	21	21	22	22
Nanty-Glo,	341	0	2	2	2	2	2
Old Cranberry,	76	3	14	15	15	15	15
Oneida,	120	0	2	3	3	3	3
Newton, (Osceola),	350	0	5	5	5	5	5
Onnalinda,	73	0	0	0	14	16	16
Robertsdale,	150	0	0	5	5	5	5
Stockton No. 4,	14	0	0	1	1	1	1
Stockton No. 6,	36	2	14	21	21	21	21
Stockton No. 8,	32	1	13	21	21	21	21
Stockton No. 7,	34	1	5	14	14	14	14
Sandy Run,	98	11	11	28	28	28	28
Slabtown,	24	1	1	1	1	1	1
Swamptown,	38	5	5	7	7	7	7
Sheppton,	123	1	6	7	7	7	7
Clarence, (Snowshoe),	404	0	3	3	3	3	3
Smith Mills,	103	0	0	3	3	3	3
Treskow,	249	0	4	9	9	9	9
Upper Lehigh,	152	52	72	80	80	81	81
Vintondale,	182	0	2	2	2	2	2
Wood,	115	0	0	2	2	2	2
Yorktown,	50	0	2	2	2	2	2
Yatesboro & Rural Valley,	305	0	0	3	3	3	3
Totals, 58,	14,687	258	635	789	805	813	813

CONTROL OF WART

In a soil-borne disease like potato wart the question of control immediately suggests several possible lines of action: The prevention of spread by quarantine; the possibility of eradication; starving out the parasite by long crop rotation; and the use of resistant or immune varieties.

The policy now being carried out for the control of wart in Pennsylvania takes all these points into consideration, and in the formation of this policy full advantage has been taken of European experience as well as of the investigations conducted by the Federal authorities, the Pennsylvania State College and Experiment Station and the Pennsylvania Bureau of Plant Industry. Moreover since this state's activities in controlling wart are relied on by the Federal Horticultural Board for the protection of the country at large, our policies from year to year have been subjected to the discussion and approval of representatives from the Federal Horticultural Board and the United States Bureau of Plant Industry. In this way the subject has been given the best judgment that the whole country has to offer.

THE WART QUARANTINE

The quarantine now in effect aims to prevent the spread of Wart to other sections of Pennsylvania and to other states; to minimize the loss from wart in the infected areas; and to bring about a total or partial reduction of the disease. The original quarantine adopted March 10, 1919, was based on the Horticultural Inspection Act of June 29, 1917, but the legislature of 1919 passed the Potato Wart Act (55) so as to give the Department special power to deal with this disease: the original quarantine has been amended from time to time to conform with this special act, to include new areas found to be infected, and to bring about desirable changes in the details of regulation, but its objects and general features have remained unchanged throughout.

The present quarantine and its regulations are as follows:

QUARANTINE NO. 6

The fact has been determined that an extremely dangerous disease of the common white potato (*Solanum tuberosum* Linn.) known as the European potato wart disease (*Chrysophlyctis endobiotica* Schilberszky) has become established at certain points in the Commonwealth of Pennsylvania, and constitutes a serious menace to potato growing in this state and in the United States.

Under authority of an Act of Legislature approved the 18th day of April, 1919, a quarantine is hereby established covering the following areas:

Luzerne County,—

Hazel and Foster Townships including the City of Hazleton and Boroughs of Freeland, West Hazleton, Jeddo and White Haven; the farm of Michael Becker in Butler Township.

Carbon County,—

Banks and Lausanne Townships in Carbon County, including the Boroughs of Beaver Meadows and Mauch Chunk.

Schuylkill County,—

McAdoo, Kelayres, Honey Brook No. 1, Honey Brook No. 2, Sheppton, Oneida, and Jackson.

Lackawanna County,—

The Third and Fourth Wards of Moosic Borough.

Cambria County,—

Dunlo, Llanfair, Lilly, Vintondale, Nanty-Glo, Beaverdale, Lloydell and Onnalinda.

Centre County,—

Snowshoe, Clarence and Newtown.

Huntingdon, Fulton and Bedford Counties,—

Woodvale, Robertsdale.

Clearfield County,—

Smith Mills, Osceola.

Armstrong County,—

Yatesboro and Rural Valley.

The following regulations relative to and governing this quarantine are hereby adopted:—

1. The planting and growing of white potatoes within the area quarantined is forbidden except under permit issued by the Secretary of Agriculture or his authorized agent.

2. Under such permit wart-immune potatoes may be grown within the quarantine area, if the following regulations are observed:

   (a) Only designated immune varieties may be grown.
   (b) Seed of these must be obtained from an authorized source.
   (c) The seed must be inspected before planting time.
   (d) An inspection will be made of the growing crop, after which the grower will be notified that he may dig whenever he desires.
   (e) All potato plants growing accidentally must be destroyed.

3. All potatoes within the quarantine area are subject to examination by an official inspector, who is empowered to condemn all diseased or suspected tubers or plants, and to require their sterilization or destruction.

4. Manure, root crop vegetables, potatoes, potato peelings, or refuse of potato plants of any kind, or any infected soil, or plants with soil about their roots, or any material which would carry this disease, are prohibited movement or removal to any point outside the quarantine area.

Exceptions:

(1) Potatoes or other vegetable crops or plants or other material originating outside the quarantined area and in transit through the quarantined area, or having been shipped into the quarantined area for immediate reshipment, shall be exempted from the quarantine restrictions.

(2) Manure may be removed during the months of January, February, October, November and December of each year, from authorized sources within the quarantine area, to points within the Safety Zone, only under permit issued by the Secretary of Agriculture or his authorized agent.

(3) Material other than manure capable of carrying the disease may be exempted by permit from the quarantine restriction, if in the judgment of the Secretary of Agriculture or his authorized agent, such substances are free from the disease, or have been satisfactorily sterilized.

(4) All potatoes other than authorized immune varieties found growing are subject to destruction.

In order to create a "Safety Zone" about certain areas infested with potato wart so as to minimize the danger of spread of the disease, Quarantine No. 6 is hereby extended to cover the following areas:

The townships of Dennison, Butler, Sugar Loaf and Black Creek in Luzerne County; the townships of North Union, East Union, Mahanoy, Delano, Klein and Rush in Schuylkill County; and the townships of Packer and Lehigh in Carbon County.

Within the "Safety Zone" so designated the following regulations are hereby adopted:

(1) The planting or growing of white potatoes within the area quarantined is forbidden except under permit issued by the Secretary of Agriculture or his authorized agent.

(2) All potatoes within this area are subject to inspection at any time.

(3) Potatoes may be shipped or removed from this area to points outside the quarantined area only under certificate of inspection.

It may be seen from a reading of the quarantine and its regulations, that the restrictive measures adopted cover three fields of activity: The movement of materials capable of carrying wart, the control of the growing of potatoes in the area under quarantine, and the so-called "Safety Zone."

Of the materials which might carry infection potatoes themselves are, of course, the most dangerous, and every effort has been made to prevent any outward movement of this crop. Fortune has been on our side in this matter since there are so few potatoes grown in the quarantined districts compared with what are consumed that

there is no natural economic outward flow to contend with. The occasional and exceptional cases of outward movement of potatoes have involved small amounts and these have been provided against as far as possible by a system of road patrol and by enlisting the aid and cooperation of railroads and common carriers to prevent these isolated infractions of the quarantine.

It should be said here that the railroad, express and other common carriers have throughout given us every possible help in keeping the quarantine intact even at the cost of considerable trouble and time.

MANURE FOUND MEANS OF SPREAD

Another material which was an outstanding source of danger was manure. The populous towns and villages produced a vast supply of stable manure yearly for which they had no use, and still greater amounts accumulated in the coal mines of the hard coal regions where horses and mules are widely used to pull coal cars. Before the quarantine was imposed, this accumulation was hauled out to the surrounding agricultural valleys, thus providing a valuable fertilizer on the one hand and getting rid of a nuisance on the other. When the quarantine was applied to this district it was impossible to think of allowing the indiscriminate distribution of such dangerous material and the movement of manure was stopped. But the economic loss to both producer and consumer was seen to be so great that an attempt was made to solve the situation by providing for sterilization of the manure. This was found to be entirely feasible and safe but in a commercial way so much was added to the cost to the farmer that the process could not be continued profitably. Finally after a study of conditions surrounding the production of manure, it was decided that the danger of contamination of some sources was so infinitely small that their product could be utilized without danger. Since then a limited amount of movement of manure has been permitted under a permit system and thus the problem has been at least partially solved.

One avenue of spread, which is exceedingly dangerous, is the movement of household goods from infected areas to points beyond the quarantine limits, since the list of articles moved usually include the tools and implements used in garden culture and very often potted plants and shrubbery. To close this avenue of spreading the disease, a careful check is kept on all persons moving out of the area. This is made possible through the assistance rendered by the coal mining companies who own most of the houses and notify us when a tenant vacates, by the common carriers who notify us of the movement of household goods, and by similar cooperation of the motor transportation companies. In addition, the public highways are patrolled during the spring and fall, and all wagons and auto trucks are subject to inspection, if the materials they are carrying originated in the Quarantine Area.

Fig. 6. A hill of potatoes from a warted garden. There are three table size tubers instead of a normal production of about ten, and all three are so affected by Wart that they will rot in storage.

Some anxiety was felt at the beginning of quarantine operations regarding the danger of wart transmission by means of commercial potted plants, shrubbery, and particularly by such things as young cabbage and tomato plants. Although the quarantine expressly forbade the movement of such products it would have been much more difficult to prevent leakage of these dangerous materials than potatoes and manure. But as the time went on and the local conditions were more thoroughly understood it was found that there was practically no danger from this source because here again the region was outstandingly a consuming rather than a producing community.

POTATO GROWING IN THE QUARANTINE AREA

The variety selected for use in the quarantine area was the Spaulding Rose, a variety which was chosen after several years' satisfactory tests of its yield, quality, and general freedom from disease. Besides being immune to Wart the Spaulding Rose has such outstanding top and tuber characters that impurities are readily detected in the growing season. In addition this variety though it is classed as a late potato sets its tubers early in the season and this feature in conjunction with its prolific bearing habit gives it decided value as an early potato. Moreover the Spaulding Rose is not grown to any appreciable extent in Pennsylvania and is not in demand in our markets, so that there is no inducement to take it out of the quarantine area or on the other hand little chance of any irregular introduction into the area of unauthorized stocks of seed.

Because of these desirable features this variety has been grown exclusively in the quarantined areas since and including 1921 and is the only variety authorized for use there. The Department of Agriculture thus controls the variety of potato grown and the source of the seed used, but does not restrict the quantity; a resident of the quarantine area may plant as many potatoes as he pleases. In order to make control measures effective from the legal point of view the permit system is used, since it is only by such system that methodical records could be obtained of all potatoes grown, or violations established with the certainty and directness required by law.

ANNUAL CANVASS IS MADE.

Each winter a canvass is made of the whole quarantine area involving some 14,000 individual visits, and permits are issued for growing potatoes during the next season. At the same time the amount of local seed of the immune variety saved for planting is ascertained and from data thus obtained the amount of new seed stock that will be needed is estimated. This seed stock has in the past been obtained either from Maine where there is a large seed trade in the Spaulding Rose, or from local Pennsylvania sources where it has been grown under supervision for this special market. The market outlet for Spaulding Rose in this state is so small that Pennsylvania growers do not care to take a chance of over production to supply this seed need and it has been a problem to supply the very fluctuating demand for immune seed without having recourse to a reserve supply such as Maine possesses.

Fig. 7. These potato plots at Drifton are planted each spring to a large number of varieties of potatoes in order to train the wart inspection staff to distinguish potato types by their top and tuber characters. This training is necessary to enable them to detect other varieties mixed with the immune Spaulding Rose. The background in this picture gives an idea of the wild uncultivated land surrounding these anthracite mining towns.

The authorized stocks of Spaulding Rose seed are bought by a wholesale merchant and distributed at a uniform price in the quarantine districts through local stores, the price to the consumer being arranged beforehand by conference with the Department. In case of lack of seed or dissatisfaction in regard to cost the growers are given full privilege to buy their own stock from a source satisfactory to the quarantine requirements, which means that it must be free from other varieties, and of a quality which will give a good yield.

Record is kept of the amount of seed delivered by the distributor to each grower, and this information in addition to the permit record and a card index giving other information about each grower with a map of his plot, enable the summer inspection to be carried out with thoroughness and rapidity. This inspection is made as soon as the potatoes are large enough to show distinct varietal characters and before the disease has had a chance to establish itself on any susceptible plants that may be present. It has taken several years of training to provide a staff of inspectors who are able to determine mixtures in the fields and garden plots under all stages of growth and surroundings, but this has been so well worked out that our men are able to pick out at once from top characters alone the impurities that may be present. Where such impurities are found they are pulled out immediately, and the owner is subject to prosecution. In the early stages of the quarantine there was some attempt to evade the quarantine by the use of other varieties or by mixing the immune seed with other varieties. A vigorous series of prosecutions soon reduced these violations and the loss of the forbidden plants has been a still stronger deterrent from such practices.

In the early years of the quarantine when many varieties were grown, a digging inspection was necessary in order to determine the presence or absence of wart; but since the universal use of Spaulding Rose the grower is allowed to dig and use his potatoes at will as soon as the summer inspection is over. He may also save them for seed the next year if he desires to do so.

GROWERS MUST PLANT ONLY ONE VARIETY.

It will be seen from this outline of the methods followed in the quarantine area that the only hardship inflicted on the districts involved is that the potato growers are restricted to one variety; and this can hardly be called a hardship since the variety is considered an excellent one, yields well, and seed of good quality is provided. That it is not a desirable market variety in Pennsylvania is of little consequence because it could not be shipped out in any case and the amount grown is far from meeting local needs. In other respects the quarantine is not burdensome; permits are issued without trouble to garden owners and after summer inspection no further supervision is given or is necessary.

It will further appear that by the system of growing immunes from which all strays are removed before wart has had a chance to develop, there is provided as good a means of starving out the organism as if no potatoes were grown.

THE SAFETY ZONE

The two principal areas infected with Wart in Pennsylvania are (a) the anthracite coal mining district centered about Hazleton and (b) scattered towns and villages in the bituminous coal districts of midwestern Pennsylvania centered about Ebensburg. These districts are actually non-agricultural and are composed of completely isolated towns and villages. In these districts there are eighty-two (82) towns and villages of which fifty-eight (58) are infected. The complete isolation of these eighty-two towns comprising the Wart infected areas is undoubtedly the greatest single factor in preventing the spread of the disease. It is quite possible to suppose that the disease will spread in each village, but the spread to points beyond the village or town limits is only possible if materials capable of spreading the disease are actually carried out, and the previously mentioned restrictive measures effectively prevent this movement.

The Wart area centered about Hazleton, is, however, surrounded by important agricultural valleys. In these valleys potatoes are the principal crop and though over 90 per cent of the potatoes grown in these valleys are marketed locally, the balance is shipped to distant markets. Though Wart has been found there on only one small farm, which is now included in the quarantined area, there is still the possibility that Wart may be present in these valleys, but to such a small extent that our surveys have not uncovered it. To avoid possible spread from this source, these agricultural districts were placed under a modified quarantine in 1922, and required to grow only specified immune varieties, the Green Mountain and Irish Cobbler. It was thought that if these were universally grown, Wart if present, would never increase and the chance of the disease being spread on the small percentage shipped out over the state would be extremely small. Aside from this restriction as to varieties no other requirements were imposed on these agricultural valleys which were aptly termed the "Safety Zone."

The use of Irish Cobbler proved successful but owing to cultural and climatic conditions, the Green Mountains developed so much scab that their market value was considerably decreased. To avoid future losses of this kind to the growers, another method of protection was tried in 1923. The varietal restriction was removed and a system of field and shipping inspection adopted in its place. No cases of Wart were found in the 1923 inspection and it is hoped that after several years close observation these important agricultural valleys will continue to be found free from the disease.

FACTS ABOUT POTATO WART QUARANTINE

The Quarantine Area

The area centering about Hazleton which is all under quarantine covers four townships in two counties and contains 120 square miles. In it are 33 towns and villages.

Outside this area 25 additional towns and villages in the anthracite and bituminous coal regions are under quarantine; in all there are 58 towns and villages included in this quarantine, scattered through 11 counties.

In the whole of the quarantined area there are 134 farms in only two of which infection is known and 14,689 gardens of which 813 or 55 per cent are known to contain Wart.

Potatoes are grown in the quarantine area to the extent of about 150,000 bushels, which requires approximately 15,000 bushels of seed yearly. In addition to the seed kept over from the previous year by the growers a supply of about 4,000 bushels must be provided yearly. In 1923 new seed was thus distributed in sealed sacks to some 1,100 individual growers.

Permits to grow potatoes were issued in 1923 to 3684 persons, involving a visit to all garden owners. Inspection of seed requires at least one visit in spring to those who plant potatoes; and the summer inspection of all fields or gardens whether planted or not entails another round of visits to all the area, or in all during the year over 30,000 visits are required.

In 1923 violations of the potato wart quarantine numbered 19 and in all these cases prosecutions were successfully conducted. This is a marked reduction from 1922 in which year there were 170 violations. Since the quarantine was instituted, 443 successful prosecutions have been made.

The Safety Zone

The Safety Zone comprises 11 townships in three counties, involving an area of 230 square miles in which there are 772 farms and 50 towns and villages, these latter containing 591 gardens in which potatoes are planted. The production of potatoes in this area is approximately 500,000 bushels yearly. In 1923, 60 per cent of the potatoes grown were immunes. Over 90 per cent of the potato crop is used locally and within the quarantined area.

THE POSSIBILITY OF ERADICATING WART

When one notes the limited and isolated nature of the areas in which Potato Wart occurs in Pennsylvania, one is led to inquire whether or not some form of eradication might be possible, since there are involved only 813 small gardens aggregating in area about one hundred acres. Even if this procedure were costly it would, if successful, solve the problem at once and forever. Many experiments have been carried out to test methods of destroying the fungus in the soil and a few of these have shown some merit. But when it comes to applying these methods to actual conditions and taking care of gardens, fence rows, walks, the bases of trees, streets, and waste land, on a 100 per cent basis the practical difficulties loom so high that the success of any such undertaking becomes a dubious matter.

Moreover it would be folly to embark on an expensive program of this kind until there was assurance that all the infested areas had be found and the whole of them could be dealt with. Unfortunately the methods used in scouting for Wart over the state, though faithfully carried out, could not in the nature of things assure us that all Wart had been discovered. There were many gardens not

growing potatoes at the time of inspection, or they were planted to immune varieties. Though the existing potatoes might be free from Wart, another part of the garden may have had Wart in previous years; and since in a hurried survey not every plant can be examined, cases of Wart may well have been overlooked. The fewness of the infections found in some towns and the difficulty in locating all affected gardens without a very intensive survey lead to strong doubts as to whether we have yet found all the existing cases of the disease. Under these circumstances a program of soil sterilization appears to be of very doubtful value.

On the other hand there is some ground for hope that by a natural process of starvation, the organism may be eliminated from the soil. The obvious course to obtain this result would be to cease the culture of potatoes entirely for a sufficient period of years, but since certain varieties are absolutely immune there seems to be no reason why the same end cannot be reached if these immunes, and these alone, are grown. This is now a part of the quarantine policy; every care is taken not only to see that the seed stock used is pure but the summer inspection is so timed that accidental or wilful impurities can be removed before Wart has had a chance to develop on them.

In this connection mention should be made of the few other hosts on which the wart organism can live, of which the most important is the tomato. This common garden plant develops a few but definite small warts on its root system and may thus serve to keep the parasite alive in the soil. The question of providing immune tomatoes for use in the quarantine areas is now being investigated.

The one or two other hosts among the nightshade family are so generally absent from the districts containing Wart that they need not be considered from the control standpoint.

THE VALUE AND USE OF IMMUNE VARIETIES

A study of the reaction of American varieties to the Potato Wart disease was undertaken in 1919 and is being continued at the time of the present writing. The fact that certain American varieties remained free from the disease in heavily infected gardens was noted in the survey work performed in the fall of 1918, and further, the reports of European variety tests which included several American varieties led us to believe that further immunity tests of our American varieties would develop other immunes. The result of these tests covering the period of 1919 and 1922, inclusive, has been recently published by the United States Department of Agriculture in Department Bulletin No. 1156.

An analysis of the immunity tests reported in the above-mentioned bulletin shows the following American varieties of commercial importance to be immune to the Wart disease. In addition, a list of important and commonly grown susceptible varieties is included to serve as an indication of the areas in which the Wart disease if introduced would cause considerable damage or necessitate changing the varieties grown to immunes:

COBBLER GROUP

Immune	*Susceptible*
Irish Cobbler	(None)
Early Petoskey	
Early Eureka	
First Early	
Flour Ball	

BLISS TRIUMPH GROUP

Immune	*Susceptible*
(None)	White Bliss Triumph
	Bliss Triumph

EARLY MICHIGAN GROUP

Immune	*Susceptible*
Early Harvest	Brown Beauty
Ehnola	Early White Albino
White Albino	Early Michigan
Extra Early Sunlight	

ROSE GROUP

Immune	*Susceptible*
Spaulding Rose	Early Rose
Northern King	White Rose

EARLY OHIO GROUP

Immune	*Susceptible*
(None)	Early Ohio
	Late Ohio
	White Ohio

HEBRON GROUP

Immune	*Susceptible*
(None)	Beauty of Hebron
	Aroostook Pride
	Early Bovee
	Country Gentleman

BURBANK GROUP

Immune	*Susceptible*
Russet Burbank	California Russet

GREEN MOUNTAIN GROUP

Immune	*Susceptible*
Green Mountain	Green Mountain (Gero Strain)
Green Mountain Jr.	Carman No. 1
Gold Coin	American Giant
Norcross	
McGregor	
Idaho Rural	

RURAL GROUP

Immune	*Susceptible*
(None)	Rural New Yorker
	Russet Rural
	Carman No. 3
	Late Petoskey
	Million Dollar
	Sir Walter Raleigh
	No. 9
	Heavy Weight
	Mason
	Dibble's Russet

PEARL GROUP

Immune	*Susceptible*
(None)	Blue Victor
	Pearl
	People's

PEACHBLOW GROUP

Immune	*Susceptible*
Red McCormick	(None)
McClure	
White McCormick	

UP-TO-DATE GROUP

Immune	*Susceptible*
(None)	Cumming's Pride
	Up-To-Date
	Dooley
	Whitcomb
	Scotch Rural

The above list of immune varieties contains only two widely known and cultivated Group types, i. e., Irish Cobbler type— as illustrated by Cobbler, Early Petoskey, etc.; early varieties, and the Green Mountain type— as illustrated by Green Mountain, Norcross, etc.; late varieties. In addition to these two groups we have the immune Spaulding Rose, Russet Burbank and McCormick; of these, "Spaulding Rose," is the only one used extensively.

For the sections of the United States where Irish Cobbler and Green Mountain varieties are grown, there is no possibility of economic loss from the Wart disease, but the areas of the United States and especially Pennsylvania that can or do grow these varieties are decidedly small.

In Pennsylvania, varieties of the susceptible Rural New Yorker group are grown almost exclusively as a late or main crop. This

means that the problem of controlling the Wart Disease by the use of immune varieties will not be solved for Pennsylvania and other states in the Rural belt until there has been developed by selection or breeding a type of potato which possesses the characteristics of the Rural New Yorker group.

Extensive experiments in breeding and selection are now in progress and the results obtained so far are very encouraging, since an immune seedling with one parent of the Rural New Yorker type is at hand; but additional study and selection will be necessary before this or some similar immune seedling of the Rural type will be available for commercial distribution.

Fig. 8. A hill of potatoes badly damaged by Potato Wart. The few small potatoes produced are perfectly good for food purposes but the yield is greatly reduced and all tubers having Wart outgrowths will rot in storage in a few weeks.

FUTURE POLICY IN POTATO WART CONTROL

In Great Britain where Wart has been most studied of all European countries this disease has long been considered a serious trouble, not only because of its persistence in the soil but also because of its gradual spread as well as the often severe damage produced in the potato crop. In America the outbreak of Wart in scattered localities in three states opened up the same dreary outlook for the future of our potato industry. Recent studies however, both here and in Europe, have changed our attitude of mind toward Wart and it is no longer considered capable of bringing about a national catastrophe. The reason for this more optimistic outlook is to be found in the results of studies of the possibilities of immune varieties.

It is still admitted that Wart is persistent in the soil, spreads insidiously if slowly, and is very destructive to the crop; but the finding of so many well-known American varieties to be immune, and still better the conclusion reached by the investigators that immunity is a hereditary quality of such a nature that it can be introduced into varieties otherwise desirable by cross breeding, both enable us to face the future without undue apprehension. In other words we can either use existing immune varieties or produce others as needed and calmly ignore the Wart menace. That such a confident outlook can be maintained is due to the somewhat unusual relationship between the potato plant and the Wart parasite. It is rare in the realm of plant disease to find cases where the immunity of the host is so perfect or so constant as it appears to be in this case, and it is not too much to say that without this fortunate relationship we would be compelled to face the future with deep misgivings.

This feeling of relief from a threatened disaster must not be allowed to run to the extreme: we still have the Wart disease, and must face the problem of what to do with it. It is true that we are secure from widespread destruction of our potato crop but only on condition that immune varieties are used wherever Wart appears. At first sight it would seem easy to remove all restrictions, allow the Wart to spread at will, and then rely on the use of immune varieties to prevent damage. Although something would be saved in the cost of quarantine by this procedure it has very serious drawbacks when examined in detail.

In the first place the immune varieties now known are more adapted to other regions than to Pennsylvania. Over 90 per cent of the potatoes grown in Pennsylvania are of the Rural type which is very susceptible to Wart and in which no immune strains have yet been found. The known immune varieties would be successful only over a comparatively small area of the state and if planted generally would not satisfy our requirements for yield, type and market demands.

It may be said that in time a variety equal in all respects to the Rural yet immune to Wart can be produced by breeding as our investigators have stated can be done. This is as yet a prom-

ise and not an accomplished fact; even granted that such a variety can be obtained, years must pass before it could come into general use. Under very favorable conditions ten years must elapse before the product of a cross could be multiplied into even 100,000 bushels.

Another consideration of great importance comes in with the question of the use of immune varieties generally. The value of such varieties depends on their purity and to secure this purity would require supervision on such an enormous scale that the final cost would far exceed the present cost of the Wart quarantine. This supervision would be almost equivalent to seed certification and while such certification would no doubt be of value to the potato industry, the cost of it on such a large scale would be very great.

Another practical difficulty arises here. Pennsylvania might attempt to solve her Wart problem by dropping restrictions and using immunes, but other states may not wish to allow free entrance of Potato Wart into their farms, and then adopt immunes. If such a policy were adopted by Pennsylvania, we might fairly expect to have all our potatoes excluded from other states. If we could not ship potatoes out of the state but had to consume all our own crop and whatever other states could sell us as well, our potato industry would undoubtedly suffer. It should be noted here that up to the present, other states and the Federal authorities have accepted the Pennsylvania quarantine as a sufficient protection to the rest of the country.

Still another point deserves careful consideration. No matter how gradually Wart might spread, and no matter how successful immune varieties might be, the appearance of Wart in any potato section or in individual farms will mean for that section or farm a restriction of sale or of variety that will surely reflect itself in lowered land values.

A further disadvantage presents itself in regard to an "open door" policy. There is at present a more or less well grounded hope that if the disease can be held to its present areas, and if within those limits nothing but immunes is allowed to grow, the fungus may be starved to death in the course of a comparatively few years. The realization of this hope would be by far the most satisfactory way of solving the Wart problem; but if restrictions were removed, this hope must be entirely abandoned and we must face a future where Wart will be forever an irritating factor in the potato industry

The disadvantages and objections enumerated above are very real and practical in their nature. When they are given due consideration one is tempted to turn from them in disappointment and to inquire what will be the situation if the present restrictions are continued.

The cost of this quarantine is not excessive and is small compared with the expense that would be involved in supervision of immune seed potatoes for large areas. This cost is also offset to

some extent by the increased value of the crops produced in the quarantined areas as a direct result of the good seed used, and also to some extent by the saving which results from correlation of work between the quarantine force and the potato seed certification staff.

The present quarantine measures do not cause any especial hardship to those concerned. The residents of the areas under quarantine, it is true, are restricted to an immune variety but it is a good one and yields well. They may grow all the potatoes they desire, plant when and how they please, and dig and use them at their pleasure. The supervision over seed is simple and the only other inspection made by the quarantine officials is in summer and does not interfere with their freedom in the slightest degree.

This somewhat lengthy explanation of the points involved in our future Wart policy may be summed up as follows:

The success with which immune varieties can be used against the Potato Wart disease both here and in Europe removes all danger of its ever becoming a national menace and raises the question as to whether the present restrictive measures might not be done away with or lessened; in other words shall the present quarantine be continued or dropped? The consequences of following each of these policies can be presented thus:

IF QUARANTINE IS DISCONTINUED

(1) In time it will be necessary to provide seed of immune varieties for all the areas into which the disease will spread, as it surely will. This practically means seed certification on a gigantic scale.

(2) This will cost at least as much as the present quarantine.

(3) Such a cost will be permanent.

(4) We have as yet only a promise of a variety to replace our widely grown Rural, not an accomplished certainty.

(5) Wherever Wart spreads, land values will be lessened.

(6) We must abandon all hope of ever getting rid of Wart.

(7) Other states not wishing to follow our example in the matter of immunes are likely to quarantine against our potatoes.

IF THE QUARANTINE IS CONTINUED

(1) Our present very susceptible Rural types, widely grown, popular, developed with great trouble, satisfactory for yield, and suited to our climate, soil and market conditions, can be kept unchanged.

(2) There is reasonable hope that under the present restrictions Wart will disappear in a comparatively few years thus ridding us forever of an unwelcome problem.

(3) The cost of the quarantine will be at least no greater than the supervisory and expert service required to introduce and maintain immune varieties over a large area of the state.

(4) The quarantine cost is likely to be limited to a few years; the other would be a permanent expense.

(5) The quarantine does not entail any special hardship to any group or person in the areas concerned. Any one in these districts can grow all the potatoes he desires.

(6) In some respects the quarantine has been beneficial; more potatoes are now being produced in the quarantined areas than before the restrictions were established.

(7) Other states which have heretofore regarded our quarantine as affording them ample protection from Wart, will no doubt continue to do so.

When all the above points are duly considered, there seems to be no question that the best policy to follow is to continue the present quarantine.